CERTIFICATE OF TRANSLATION

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Planar antenna

МПК7 H01Q 13/20

The Invention relates to radio engineering, particularly, to antenna systems and can be applied in communication systems, radiolocation and satellite TV.
Planar antennas have small dimensions and are widely used in different wave bands.

Plane antennas have big losses in centimeter and millimeter band, that is why, antennas as arrays of metal waveguides of the leaky wave are used more frequently. Such antennas allow to provide low losses and operation on two polarizations [1]. Complex manufacturing technology and high weight refer to disadvantages of such antennas.

There is an antenna based on planar metal dielectric antenna waveguide with central power and normal radiation that provide activity in two polarizations and that is free from the said disadvantages [2]. The disadvantage of this antenna is relatively big band pass of operation frequencies not exceeding, as a rule, several percents from the determined by the matching according to input due to resonance reflection. The similar disadvantage according to similar reason has antenna [3] that has more complex two-layer structure.

The closest analog is antenna of leaky wave comprising planar dielectric waveguide with 2D array of dielectric radiators and two orthogonally located linear exciters, it can provide operation in two polarizations [4]. The disadvantage of this antenna is narrow frequency band, determined by divergence of directions of wave radiation with orthogonal polarizations due to frequency scanning.

The aim of the claimed Invention is generation of two-polarization antenna operating in wide frequency band on the basis of metal dielectric waveguide.

The technical result is achieved by the fact that antenna comprises planar plated, at least from one side, dielectric waveguide to the sides of which metal waveguides joined with planar waveguide via periodical array of slots, are connected, at that array comprises two slots shifted or inclined according to each other, on the surface of the planar waveguide in the rhombic mesh point with radiating elements, having two symmetry planes, at that:

Planar antenna can be characterized by the fact that it has form of rhomb.

Planar antenna can be characterized by the fact that metal waveguide has rectangular cross-section.

Planar antenna can be characterized by the fact that metal waveguides are contacting with planar ones by wide sides.

Planar antenna can be characterized by the fact that metal waveguides are contacting with planar ones by narrow sides.

The essence of the Invention is explained by the drawings in which:

Fig.1 – demonstrates general view of planar antenna of the Invention

Fig.2 – demonstrates mesh in points of which there are radiating elements

Fig.3 – demonstrates feeding waveguide with communication slots.

Fig.4 – demonstrates spherical system of coordinates

Fig.5- demonstrates radiating element

Overall view of the claimed antenna is presented in Fig.1. Antenna consists of the following elements:

- feeding waveguide 1;
- feeding waveguide 2;
- plane waveguide, generated by the dielectric plate with one or two dielectric surfaces;
- array of radiating elements 3, generated by the inhomogeneity on the surface of dielectric (metal or dielectric) or on the metal (in the form of corrugation, slots, etc.)

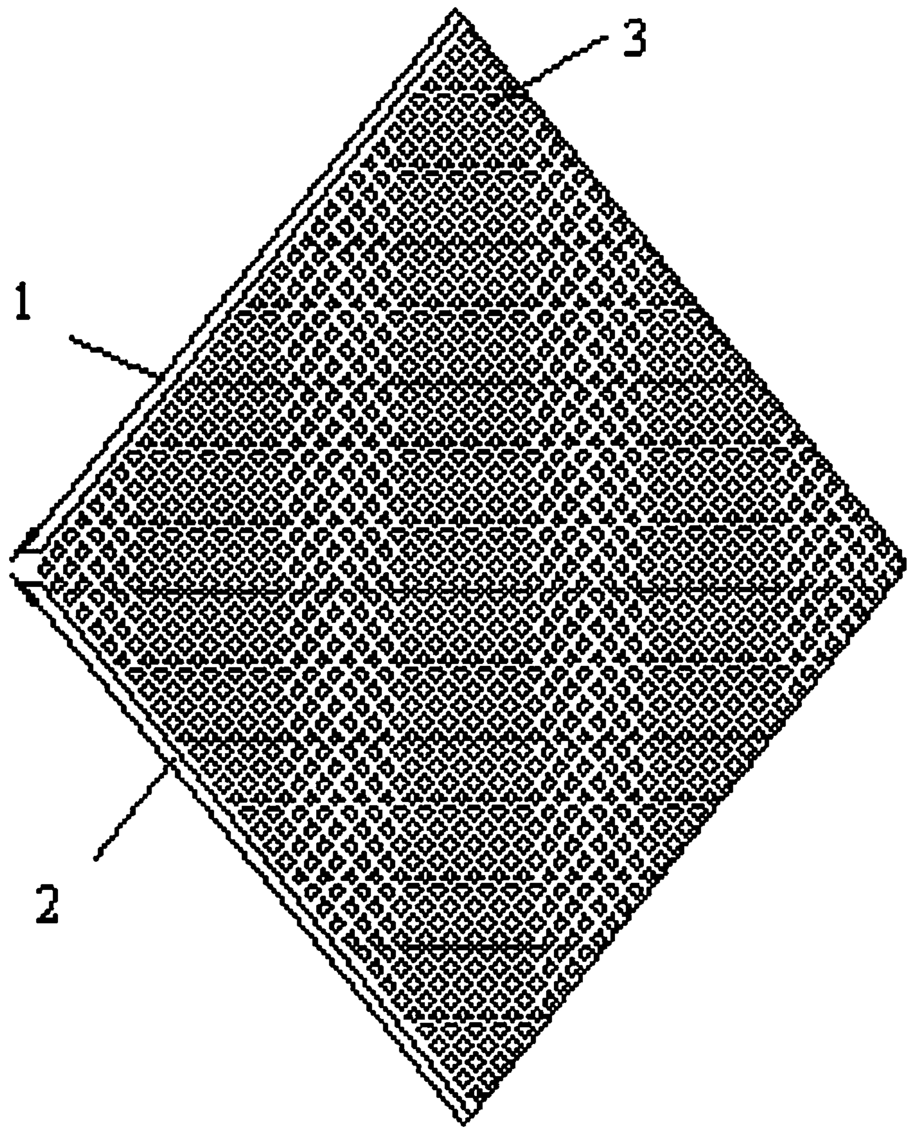
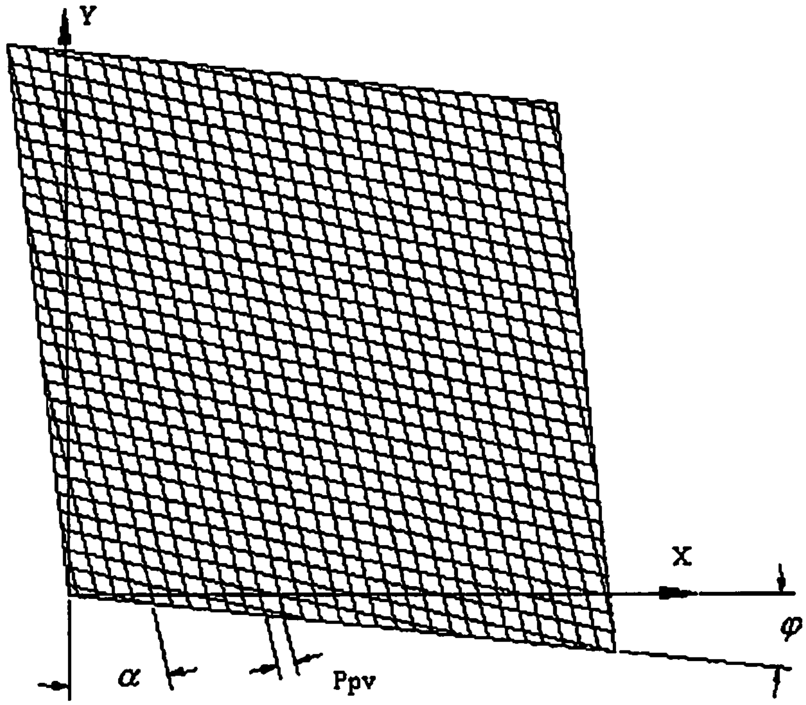


Fig.1

Plane waveguide has form of rhomb. It can also have another form.

Fig.2a demonstrates rhombic mesh in the points of which there are radiating elements. From the drawing it is seen that angle of inclination of waveguides according to orthogonal axes and inclination angles of mesh lines are not equal to zero and not equal to each other.

Axis of coordinates and orientation of the radiating arrays



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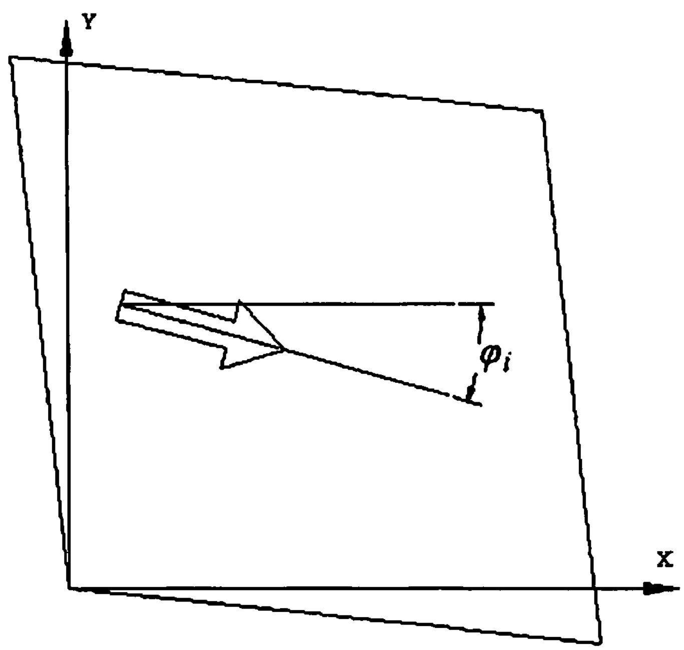

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Fig. 2

Waveguides 1 and 2 provide excitement of plane waveguide and array on its basis that converts 2D wave beam into waves of radiation of free space. Communication of waveguide with plane waveguide is provided by means of system of holes and slots, implemented in wide and narrow side of waveguide that are in the area of sealing of waveguide 1,2 with plane waveguides. Waveguides with linear array of slots is demonstrated in Fig.3.

Feeding waveguide

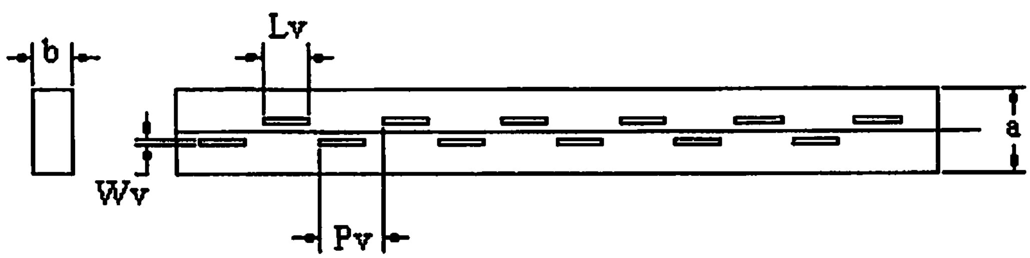

Fig. 3

In general case size of slots and their shifting from the waveguide axis can vary along the waveguide. From one side a waveguide has flange for connection with external devices and from the other matched load.

Lets review antenna in the transmitting mode. The wave of the waveguide going along the array of slots excites them and slots in their turn excite the main wave of waveguide that is T-wave with propagation constant γ_{pw} equal to $k\sqrt{\varepsilon}$, k- wave number of free space, and ε - relative dielectric penetrability of plane waveguide. In case thickness of the plane waveguide is selected in accordance with the following equation:

$$h < \frac{\lambda}{2\sqrt{\varepsilon}}, \qquad (1)$$

in which h – thickness of plane waveguide, and λ - wave length in free space so, in plane waveguide there is one propagating wave.

Constant of propagation of the rectangular metal waveguide γ_w is determined by the following relation:

$$\gamma_w = \sqrt{k^2 - \left(\frac{\pi}{a}\right)^2}, \tag{2}$$

in which a – size of wide waveguide side. It is known that linear array can radiate on different space Floquet harmonics. Since wave in the waveguide is fast wave and plane waveguide has dielectric-filled waveguide, radiation in plane waveguide can be executed on zero harmonics. In order to have proper antenna operation radiation has to be performed on minus the first harmonic. In order to delete radiation of zero Floquet harmonic the slots are located in chequer-wise. Such slots location leads to additional phase shift of slots equal to π that is virtual to wave retardation increase of the waveguide according to $\frac{\pi}{kP_w}$, in which P_w is distance between slots (see Fig.3). As the result by the selection of the determined distance we delete undesirable radiation on zero harmonic and remain the desirable on minus the first harmonic. In arrays with serial feeding it is known effect of resonance reflection that is present when array period is divisible to half of wave length in the waveguide. From the other side radiation from the waveguide on minus the thirst is possible with big enough periods. That is why the distance between the slots has to be taken from the equation:

$$0 < \frac{\pi}{P_w} - \gamma_w < \gamma_{pw}.$$

Fields excited by different slots generate 2D wave beam that is propagated in plane XOY. Angle between the direction of beam propagation and axis 0x (vertical waveguide is excited) can be reflected as follows:

$$\varphi_i = \arcsin\left(\frac{\frac{\pi}{P_w} - \gamma_w}{\gamma_{pw}}\right) - \varphi, \tag{3}$$

in which φ - angle between waveguide and axis 0y.

Distribution of field in the direction orthogonal to direction of beam propagation is mainly determined by parameters of slot array. For example, if all slots in it are of the same size, the amplitude propagation has exponentional character. It is possible to vary amplitude propagation and make it closer to uniform by making slots of different sizes. Field distribution along direction of beam propagation has character of the running wave.

Going along of array elements, the beam excites them and generates radiation in free space. It is seen that in common case beam is propagated under some angle to the mesh lines in the points if which there are array radiators (F9g.2). Radiation from plane waveguide into free space is possible to describe in terms of space harmonics. Operational mode for this antenna is radiation on minus the first harmonic. There are limitations for such antenna that are similar to limitations for waveguiding array:

$$\frac{\pi}{\gamma_{pw}} < P_{pw} < \frac{2\pi}{\gamma_{pw}}.$$

It is convenient to present radiation characteristics in spherical system of coordinates, presented in Fig.4. Angle θ - is angle of the place, and angle φ - is azimuth angle. Radiation direction from the array coincides with maximum of the antenna pattern is specified by angles θ_m and φ_m. For proper antenna operation angle φ_m has to be close to 45 degrees. In this case azimuth angles of radiation at excitement on both inputs are close to each other due to antenna symmetry. Due to the same symmetry angles of places of maximum radiation of both channels are coinciding.

Closeness of φ_m to 45 degrees is provided by the specific selection of waveguide parameters, slot array and radiating array based on plane waveguide.

Approximately size of wide side of waveguide a and period of the radiating array P_{pw} can be got from different formulas:

$$a=\frac{\pi}{\sqrt{k^2-\nu^2}},$$

$$P_{pw}=\frac{2\pi}{\left(\frac{\pi}{P_w}-\gamma_w\right)\frac{\cos(\varphi)+\sin(\varphi)}{\cos(\alpha)-\sin(\alpha)}+\sqrt{\varepsilon k^2-\left(\frac{\pi}{P_w}-\gamma_w\right)^2}\frac{\cos(\varphi)-\sin(\varphi)}{\cos(\alpha)-\sin(\alpha)}},$$

$$\nu=-\frac{B}{A}+\sqrt{\left(\frac{B}{A}\right)^2-\frac{C}{A}},A=(\varepsilon-1)^2+\mu^2,B=\frac{\pi}{P_w}\left((\varepsilon-1)^2-\mu^2\right),$$

$$C=\left(\frac{\pi}{P_w}\right)^2-\mu^2\left(\varepsilon k^2-\left(\frac{\pi}{P_w}\right)^2\right),\mu=\frac{1+tg(\varphi)}{1-tg(\varphi)}$$

(4)

At that we provide radiation regarding to both channels in one direction in some frequency range.

At that angle θ_m depends on frequency. Due to the fact that it is equal for both channels, this dependence does not lead to divergence of beams in space.

A very important antenna characteristic is radiation polarization. Normal operational mode of the claimed device is wave radiation mode of orthogonal polarization at antenna excitement from the sides of its different inputs. Since radiating element is a hole in metal screen, the determining factor will be distribution of electric field and appropriate magnetic currents in the hole. Field formation in the radiating element is explained by fig. 5. In case the hole has square form, it has properties close to properties of scalar radiator at not big dimensions. Characteristic feature of such radiator is the fact that polarization of its radiation is fully determined by the reference angle of the exciting wave.

Spherical system of coordinates

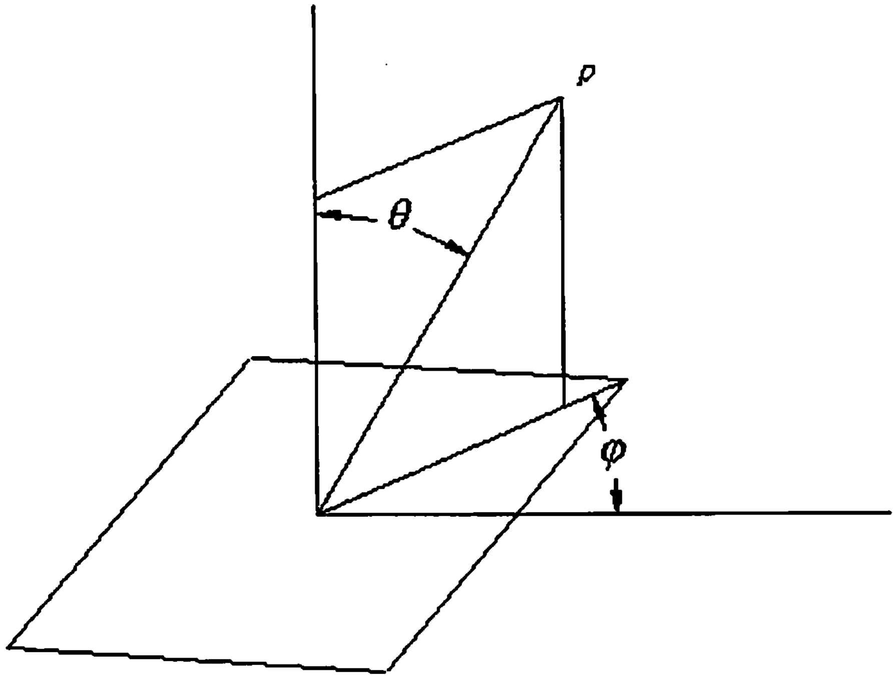

Fig.4

Fig.5 demonstrates two cases of hole excitement by waves E_{i1} and E_{i2}. Arrows indicates deviations of its propagation. They are complying with directions of wave beam propagation of the excited waveguides 1 and 2 of the claimed antenna. Field in the hole can be presented as vector sum of two modes E_1 and E_2 that are fully identical to each other besides orientation of vectors of electric field that are orthogonal to each other. Full field in the hole is vector sum of field of two modes:

$$E = a_1 E_1 + a_2 E_2,$$

in which $a_{1,2}$ – coefficients of modes. Excitement coefficients are proportional to scalar product of vector of electric current of exciting wave (it is oriented along direction of wave propagation) and vectors E_1 and E_2. It is not difficult to become sure that in this case total vector of electric field in the hole is oriented along direction of propagation of impinging wave of plane waveguide.

Orientation of the electric field in radiating element

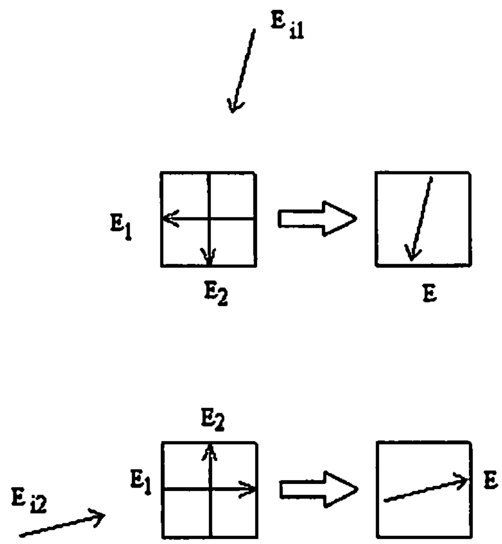

Fig. 5

In Fig.5 it is seen that due to the fact that directions of beams propagation of excited by different waveguides are not orthogonal, so vectors in the holes are not orthogonal. However, it does not follow that waves of free space can be also not orthogonally polarized. The fact is that antenna radiates under the angle to its plane, and in this case in order to get orthogonal polarized waves in free space we should have not orthogonally oriented radiators on the plane. The results demonstrated below identify that in this structure of wave polarization radiations are close to orthogonal.

In the claimed antenna there are limitations according to parameters selection. One of them is connected with condition of single-wave propagation of plane waveguide wave in 2D array. In spite the fact that plane waveguide is one-mode waveguide, periodicity of the structure can lead to appearance of propagating waves of the highest type. Absence conditions of such waves have the following view:

$$\left(\frac{2\pi}{P_{pw}}+\beta_1\right)\frac{1}{\gamma_{pw}}>1, \qquad (5)$$

$$\beta_1=\beta_0\cos(2\alpha)-\kappa_0\sin(2\alpha),\ \beta_0=\gamma_{pw}\sin(\varphi_i),\ \kappa_0=\gamma_{pw}\cos(\varphi_i).$$

Angle φ_i is demonstrated in Fig. 26. Execution of (5) with (4) automatically provides absence of subordinate diffractional maximums in antenna patterns.

Implementation of the patenting antenna is preceded by the parameters selection basing on specific requirements. Band of operational frequency and antenna gain coefficient are identified. Then dielectric is selected on the basis of which plane waveguide is executed, kind of radiator, it is selected period of slots location in metal waveguide, size of wide side of waveguide, period of radiating array from condition (4), providing radiation by both channels in one direction and inequations, excluding resonance reflection from the arrays in the waveguide and in plane waveguides, applying methods of solution of electro dynamical tasks and proper software, sizes of holes are selected providing the required amplitude distribution in plane waveguides.

Let's review example of concrete implementation of the reviewed antenna. Geometric and electric parameters are specified below.

Size of wide side of waveguide is a=14.3

Size of narrow side of waveguide is b=8

Period of slots location in waveguide is Pv=11

Width of slot in the waveguide is W_v=1

Slot length in the waveguide is L_v=6.9

Shifting of slots in the waveguide according to the centre of the wide side is x_0=2

Thickness of the plane waveguide is h=5.5

Dielectric penetrability of plane waveguide is ε=2.2

Array period in plane waveguide is P_{pw}=11.7

Dimensions of sides of square slot radiator is W=6.2

Inclination angle of the waveguide according to the coordinate axis is φ=6 degrees

Inclination angle of the lines of the array according to the coordinate axis is $\alpha = 6$ degrees.

All sizes are in millimeters. Diagrams below are got as a result of numerical simulation. This antenna has strictly periodical arrays of slots in the waveguide and

in the plane waveguide. That means that amplitude field distribution in antenna aperture has exponentially decaying character as along lines of parallel to waveguide and in orthogonal direction. Inequality of amplitude distribution leads to dropping of aperture efficiency of antenna. The maximum value of aperture efficiency losses at experimental distribution according to both coordinates is 2 decibel. It is got at some optimal value of exponent factor that is known in the theory of aperture antennas. Thus exponent factors (coefficient of wave attenuation in the waveguide and plane waveguide) depends on frequency, the maximum aperture efficiency is achieved in some fixed frequency. In the frequency band this condition is not fulfilled, so that leads to additional decrease of aperture efficiency. Exactly this factor along with inequation (5) limits operational frequency band of antenna. In this example it is equal to 10%. Due to this fact all calculations were performed in this frequency band.

Fig.6 demonstrates frequency dependence of angle of incidence of wave beam.

Frequency dependence of angle of incidence of wave beam.

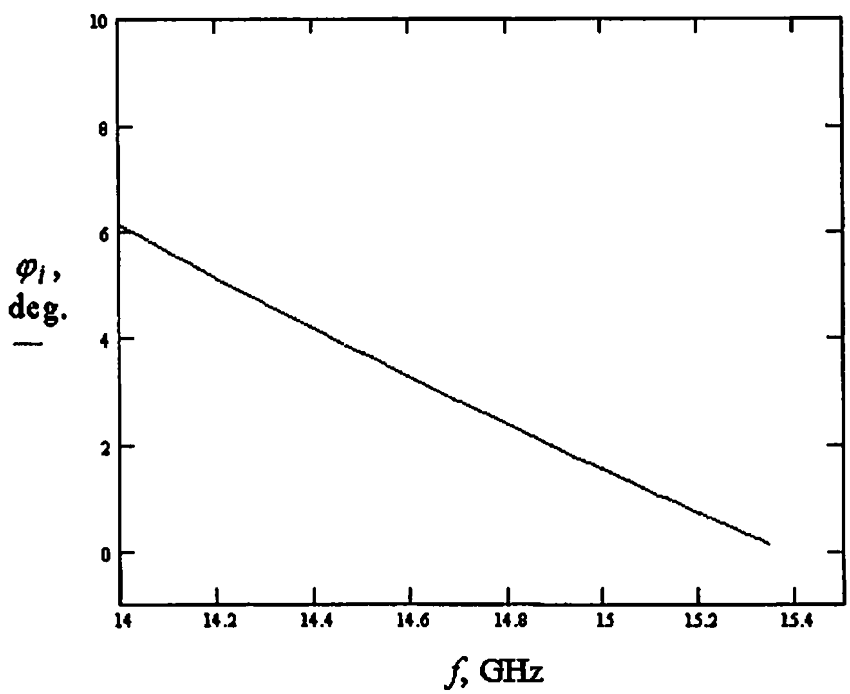

Fig. 6

On the fixed frequency it is possible to select outline of plane waveguide the way that the beam is propagating along its borders. At that outline has form of rhomb and aperture efficiency is maximum. At frequency variation the angle of wave beam is changing, that reduces antenna efficiency, because during deviation of the beam its area is not fully used. However in operational frequency band this effect is weakly developed, due to the fact that angle of incidence varies not more than for 6 degrees.

Fig.7,8 demonstrates frequency dependence of radiation angles in elevation and azimuth planes.

Frequency dependence of radiation angle in elevation plane

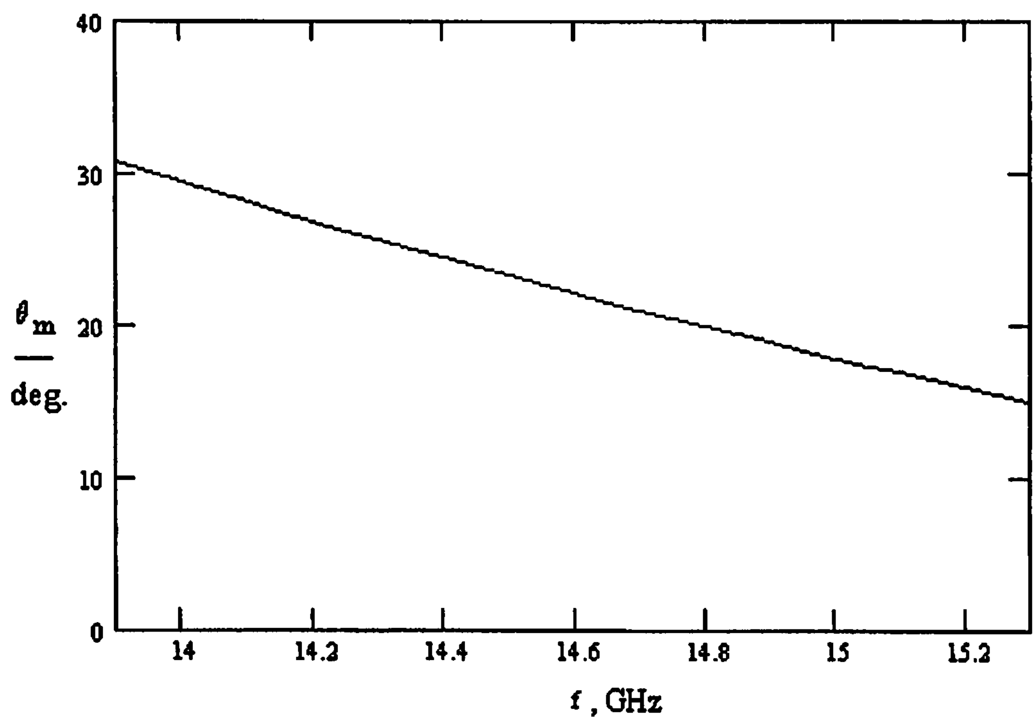

Fig. 7

Frequency dependence of radiation angle in azimuth plane

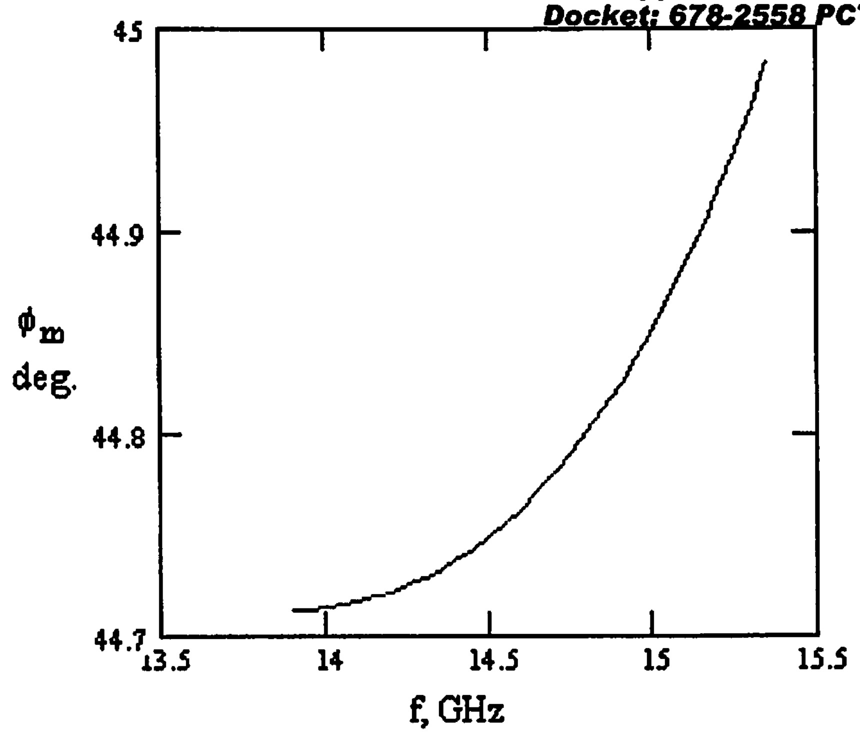

Fig. 8

Fig. 9 demonstrates dependence between maximums of patterns and various channels depending on its frequency.

Divergence of beams excited in different channels.

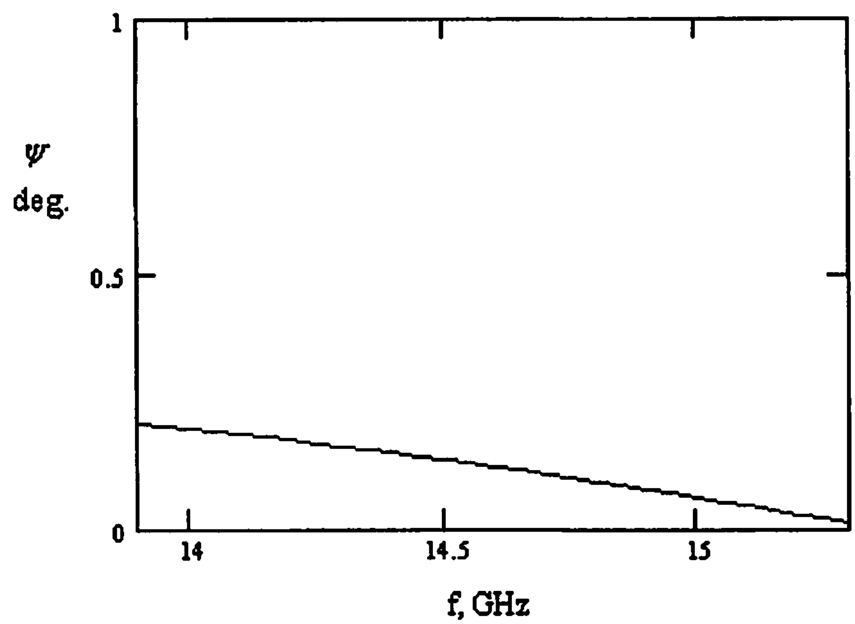

Fig. 9

Fig.10,11 demonstrates normalized antenna patterns in two orthogonal planes: elevation and azimuth at exponential distribution in aperture. It takes on itself low level of side lobes in both planes.

Pattern in elevation plane.

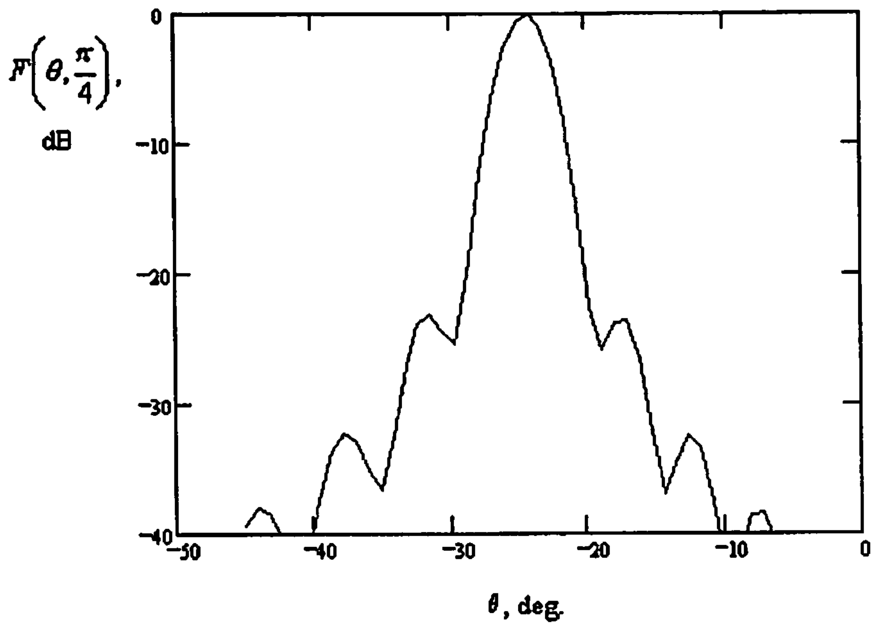

Fig. 10

Pattern in azimuth plane

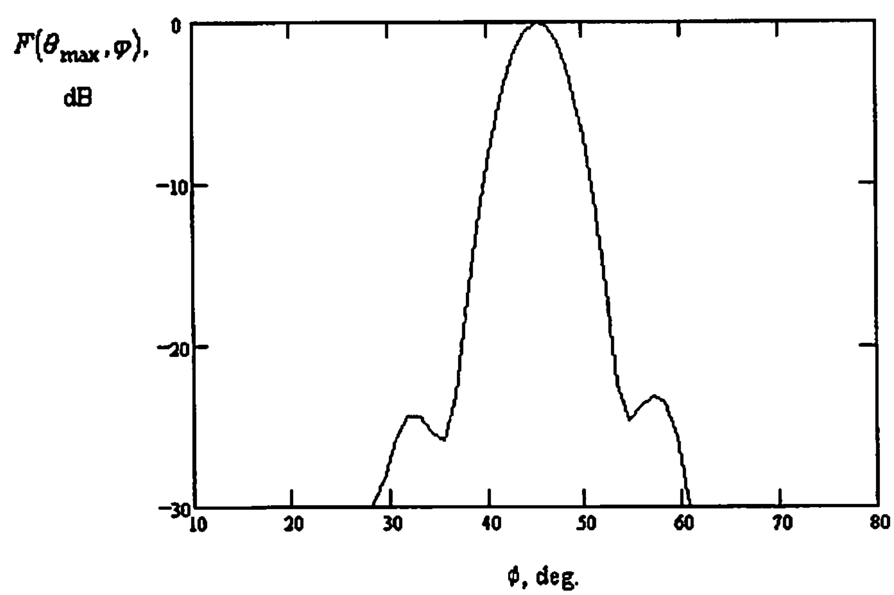

Fig. 11

Fig.12 demonstrates frequency dependence of the cross-polarization, determined by angle between vectors of the electric field in the fare field at antenna excitement from different inputs.

Cross-polarization angle

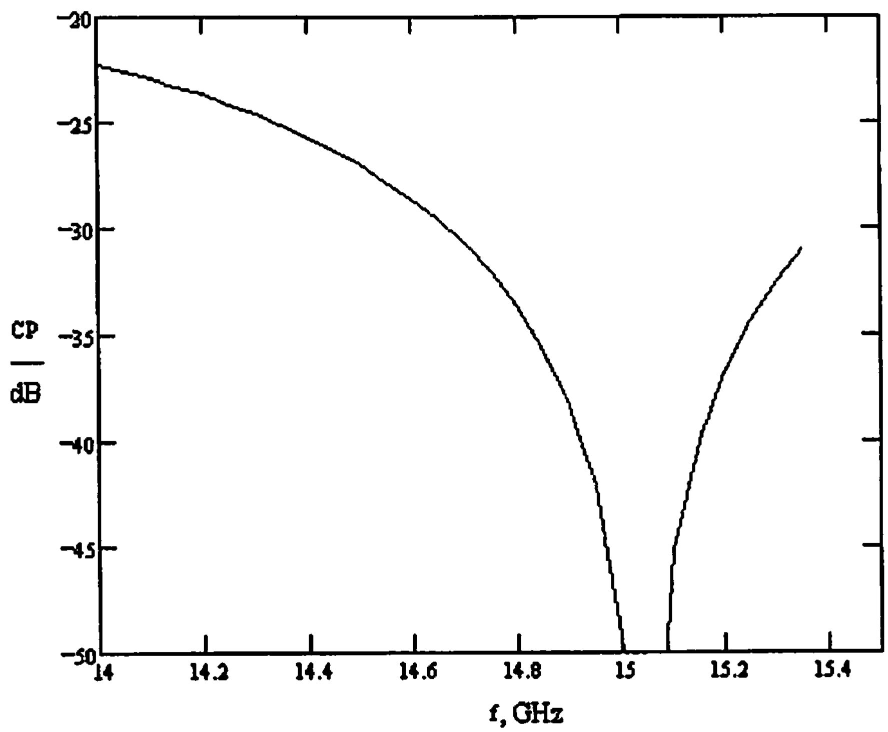

Fig. 12

Fig.13 demonstrates frequency characteristics of dependence of aperture efficiency for two different distribution in antenna aperture. Curve 2 matches exponential distribution along two coordinates. Curve 1 matches uniform distribution in the waveguide and exponential and orthogonal direction.

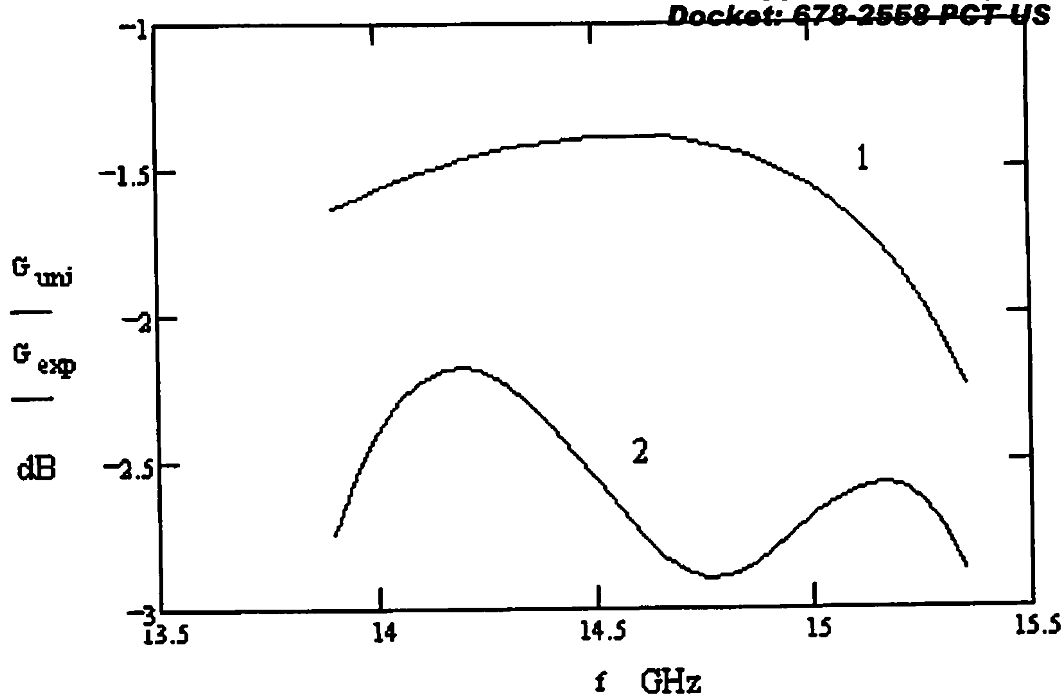

Fig. 13

The received results indicate that patenting antenna allows to provide wide band of operational frequencies (about 10%). At that slots in the waveguide can be executed by the traditional technology (mechanical processing) and radiators in plane waveguide by means of technology of the printed circuits (photolithography with further etching) in case of slot or strip radiators and also by pressing in case of dielectric radiators.

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Literature

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Claim

1. Planar antenna comprising

Planar plated at least from one side dielectric waveguide, to the side walls of which two metal waveguides are adjoining that are connected with planar waveguide via periodical array of slots, at that array period comprises two slots, shifted or inclined according to each other, on the surface of the planar waveguide in the points of the rhombic mesh with radiating elements that have two plain symmetries.

2. Device on claim 1 in which

planar waveguide has form of rhomb.

3. Device on claim 1 in which

metal waveguides have rectangular cross-section.

4. Device on claim 3 in which

metal waveguides are contacting with planar ones by its wide sides.

5. Device on claim 3 in which

metal waveguides are contacting with planar ones by its narrow sides.

6. Device on claim 1 in which

Plane waveguide is plated by two sides and radiating elements are implemented in the form of square or round holes in one of metallizations .

7. Device on claim 1 in which plane waveguide is plated from one side, and radiating elements are implemented as metallizations having square or round form.